



USAF PRAM PROGRAM FINAL REPORT



SMART Shop
WR-ALC/LYPDD

Avionics Management Production Division
Warner Robins Air Logistics Center
Robins Air Force Base, Georgia

23 February 1993

Approved for Public Distribution

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Approved by:

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1. EXECUTIVE SUMMARY

The Avionics Management Production Division (WR-ALC/LYP) performs depot maintenance on 125,800 end items per year from more than 20 different aircraft. The basic depot maintenance philosophy has been to test an end item until a faulty function is found and then to narrow the test to identify a failed component. No visibility was given to the prior performance or failure history. No one knew if a particular end item was frequently visiting the depot with the same or similar failures. Test and repair technicians did not have an on-line data collection and retrieval method of documenting and evaluating repair process improvement efforts. An excessive amount of time was spent manually processing data to and from management data systems external to the depot shop.

A bar code based end item tracking and data collection system was designed for testing on four avionics production lines. A high priority was given to providing features which would replace paper-based tasks with bar code scanning techniques. Databases and application programs hosted on minicomputers would log test and repair data as it occurred. The accumulated history would immediately be available at terminals in the shop area. End item status, failure and repair data, replaced components, and field generated performance information were included. Information required by external data systems was assimilated and transferred electronically. The project was given the name SMART Shop (Statistical Maintenance And Repair Techniques).

This project gives the depot shop an on-line electronic data resource to record test and repair actions as they occur. The data is instantly available at any other workstation to which the end item may go. The technician also has access to information relating to field reports of the end item's performance and all prior test and repair actions. A major feature of the project is that it allows documenting and evaluating of any repair process improvement effort without setting up a stand-alone database for tracking purposes. By replacing workbooks, maintenance data collection forms, inventory logbooks, and parts ordering forms with bar code scanning technology and electronic data communications, the average end item labor requirement is reduced by 35 minutes.

Follow-on implementation throughout the 38 production lines of the division will take about 2 years. Approximately \$376,400 will be expended for bar code readers, bar code printers, and port concentrators. A sufficient number of terminals and report printers have been acquired through reutilization. Implementation is expected to be complete in 1995.

The PRAM investment was \$32,505 for bar code technology and \$90,000 for programming talent. PRAM investment plus implementation cost equals \$522,505. The man-hour savings to be generated through bar code scanning and electronic data communications equals 65,625 hours per year.

2. INTRODUCTION

Avionics items received for depot maintenance have either failed in flight or failed check-out tests prior to flight. In the depot shop, they are subjected to a series of inspections, tests, and repair actions in a production line environment. An individual item may be taken apart, and the subassemblies sent to different workstations. A single subassembly may require work at multiple workstations. After subassembly test and repair, the item is reassembled and again tested and inspected. During the depot shop cycle, several technicians with various skills and specialties are involved with the item.

Four general types of regulatory requirements have to be satisfied in the depot shop. They are as follow:

- a. Material Inventory--To verify responsibility for items and repair parts in the shop.
- b. Skills Certification--To verify integrity of repairs and material handling.
- c. Technical Orders--To verify compliance with repair techniques and replacement parts suitability.
- d. Cost Accounting--To verify cost of labor, overhead, and replacement parts.

These requirements are satisfied through the use of paper forms, logbooks, and keyboarding through remote terminals into various data systems which are external to the depot shop. If an item is the subject of a Total Quality Management (TQM) project or other process improvement effort, it creates additional requirements for documentation and evaluation.

In 1987, several items produced by the F-15 avionics depot shop (WR-ALC/LYPDD) were flagged as Bad Actors. Attempts to determine cause-and-effect relationships were useless due to a lack of repair history in the shop. A stand-alone database was set up on a personal computer (PC) to record data from the AFTO Form 349 before the form was sent out of the shop. Some outside influences on the depot shop were beginning to occur at that time, too. Added emphasis was being placed on customer satisfaction. Quality People, Process, Performance, and Product (QP4) was changing to TQM, and the number of people in government employment was decreasing. Also, we were advised to prepare for steadily decreasing budgets in future years.

WR-ALC/LYP authorized WR-ALC/LYPDD to develop and prototype a technical data collection and retrieval system applicable to the entire division. Project management responsibility was given to Verlon Gilbreath of LYPDD. All the branches within the division were involved in the planning of the project. The Avionics Management Directorate (WR-ALC/LY) provided support in gaining the cooperation of other directorates affected by the project. The organizations who signed for approval of the project were: WR-ALC/CV, CN, SE, DS, PM, TQ, TI, and LY.

3. TECHNICAL INVESTIGATION

Statement of the Problem

The avionics depot shop had no knowledge of a developing problem with items it produced until a formal investigation was begun. Even then, data collecting began only after the problem's existence became known. There was no serial number history being recorded, and the maintenance data collection system was not appropriate for technical analysis.

Investigation and Findings

As data on high workload items began to accumulate in the PC database, it was evident that some items were repeatedly being sent to the depot with very little flying time. While comparing the database with old logbooks (which contained no repair history), it was found that some serial numbers were chronic failures, while others were quite random. We also found that some field organizations generated more chronic failures than others. Unfortunately, there was a total absence of any data describing earlier failures and repair actions. The depot shop worked in an information vacuum. The philosophy was to simply test the item to identify a faulty component then replace the component and send the item back out. There was no way to evaluate a current item failure and relate it to any pattern, trend, performance anomaly, unsuitable replacement part, insufficient testing, or inadequate inspection.

End items which had been identified as "problem items" had to have data collected manually during depot test and repair. This was accomplished by the technicians using paper forms or logbooks. The data was turned over to the technical services group or engineering and was not kept in the shop. Items which were the subject of an improvement action, such as a suggestion or quality team effort, also required manual data collection. Although this data stayed in the shop, it was limited in scope and availability. Data collection methods existed only for items which had a known need for improvement.

The majority of end items flow through the shop with no problems identified and no ongoing improvement efforts--and no data collection. That is a problem. Every item is a candidate for increased serviceable life and decreased maintenance cost. Without technical data collection, there is no mechanism for evaluating repair effectiveness or repair procedure efficiency. Both of those factors are key issues in a competitive environment.

It was also found that the shop is burdened with meeting regulatory requirements. The four general categories were listed in the introduction on page 2. Satisfying these requirements through filling out paper forms and keyboarding at remote terminals takes an average of 35 minutes per end item. Obviously, the present economic context demands relief for our depot shops to become competitive. The time spent on paper work could best be translated into a combination of increased serviceable life for the end item, reduced repair cost, reduced repair time, and increased throughput.

Technical Approach

The first step in data collection is to identify the subject of the data with consistent accuracy. This implies replacing the error prone human element with machine readability and standardization. In this case, bar code was chosen for its accuracy, and the end item national stock number (NSN) and serial number were chosen for standardization since they are the most common identifiers in use in the Air Force.

We needed to make sure that bar code scanning and data input were done consistently on every item. Our investigation showed that each item has at least 20 points during the shop flow where there is mandatory manual interaction with some regulatory data system. These points begin with Supply transferring inventory responsibility to the shop, which includes satisfying work control document requirements and recording parts replaced, and ends with giving inventory control back to Supply. By replacing these manual actions with bar code scanning, we could be sure the scans would be done. Our computers could handle the data interchange with the external data systems electronically while we gather the technical data we need. The shop gains a major economic benefit by reducing the 35 minutes spent on paper forms and keyboarding by about 90 percent.

The earliest equipment plan called for a customized network of PCs to host the bar code reading capability and localized databases. The prime data storage repository would be a minicomputer fed by the PCs. That plan was scrapped due mainly to regulatory authority being opposed to placing microcomputers in a production area. A second plan was developed in which multiple minicomputers working in a mirror image configuration would host all the bar code reading capability through a network of port concentrators. The minicomputers would also host the databases and application programs and handle electronic data communications with external data systems. Six minicomputers and dozens of terminals and printers were acquired through reutilization of existing inventory.

Four production lines in WR-ALC/LYPDD were chosen as a prototype shop. These lines comprised the F-15 avionics depot and were made up of automatic, semiautomatic, and manual testers with repair areas, plus a full compliment of intermediate level test stations. The variety and volume of workload in this prototype area would be representative of just about any shop configuration that would be encountered in the follow-on implementation.

Hand-held bar code scanning wands were placed at every technician's workstation. Each work group (from 5 to 7 technicians) was given an interactive terminal and dot matrix printer. A bar code printer was placed on each production line. A terminal and dot matrix printer were installed for each line supervisor. Also, bar code readers and terminals were placed at strategic points where end items entered and exited the shop and where replacement parts were stored. All these devices were linked to the project's minicomputers through a network of port concentrators. All of the data collecting and interactive devices had programmable controllers. The minicomputers initially downloaded programs into the controllers and then simply became a database server and data communications controller.

When an end item is given to the shop by Supply, bar code scanning acknowledges to the depot supply stock control and distribution system that the shop now accepts responsibility for it, and its "in transit" status is cleared. A data record is created for the item's current depot visit and an electronic version of the work control document is downloaded from the G028 Maintenance Engineering Data System. If the item is part of a contract workload, two-level maintenance, or other special category, added records are created as appropriate.

At the first workstation in the shop, scanning the item's bar code results in a search of both internal and external databases to determine if the item has any prior "problem history" or ongoing improvement efforts. If so, its electronic work control document may be amended to include additional tests or inspections. The technician is advised of the item's status, and a printout can be made if desired. Also, the technician's certification for the task being performed is verified. If the certification is invalid, or if there is a compromise of the work control document, the line supervisor's terminal is sent an error message, and an entry is placed in the supervisor's log file. This type of error would have to be manually corrected by the supervisor before the item's status could be advanced again.

Field level performance of items is obtained through a combination of methods. Some field organizations are very receptive to a project such as this and are willing to upload data through either modems or Defense Data Network (DDN) links or even send diskettes to the depot shop. Other organizations such as the F-15 and F-16 wings have Tactical Interim Core Automated Maintenance System (CAMS) and Reliability Engineering Management Information System (REMIS) Reporting System (TICARRS) fed by CAMS. We extract data from a TICARRS link. In many cases we only get DD Form 1577-2 (green tag) and AFTO Form 358 and log the data in ourselves. However, this project should exemplify the long-term benefits of data collection and be a driving force in establishing permanent data transfer methods.

As the end item moves from one workstation to another, the bar code scanning is repeated to replace stamping of work control documents and filling out paper forms as was done prior to the project. Additional data is scanned from bar-coded sheets or input at terminals located within the work groups. Information such as failed test number, failed test value, and all replaced parts is gathered on every item. Other data can be added at the technician's discretion.

Items which have a "problem history" or ongoing improvement effort require additional data input. Depending upon the specific end item, we may record the value of certain tests which pass, make an ASCII description of an inspection, add information related to a substitute component, or identify the use of a peculiar diagnostic algorithm in an automated test station.

In the past, more time was spent "doing the paperwork" to replace a failed component than was sometimes required to make the actual replacement. Unfortunately, none of the paperwork was of any benefit to evaluating the effectiveness of the replacement. In fact, it was not even part of the end item's history. This project has been designed to gather the replacement data and then leverage the central processing unit (CPU) power by finding the national stock number of the component to be replaced, make the charge-out to

the production control number, and certify receipt of the part to the shop. The project also has capabilities to decrease the labor intensity of maintaining either bench stock or Material Inventory Center (MIC) stock.

The overall approach is to provide the depot shop with an on-line data collection and evaluation tool. We wanted to make it literally a part of the workaday routine of testing and repair.

Conclusions and Recommendations

The results of the project are threefold:

a. The shop has a tool with which to document and evaluate any improvement effort. It will not be necessary to consider whether the improvement's benefit will recoup the cost of study and analysis. Now, every end item and every step in testing and repair are candidates for improvement. More effort can be concentrated on increasing the serviceable life of end items and decreasing the number of problem items. Statistical techniques can be used on accumulated data to search for potential improvements even on items without known problems.

b. The shop can approach a current repair with emphasis on trends, patterns, and tendencies. The day should come when the depot can detect a developing problem before it requires a formal investigation.

c. A substantial economic benefit will be realized through the electronic data communications techniques of the project. It is these techniques which allow replacement of paper forms, work control documents, logbooks, etc. Implementation on the 38 production lines of WR-ALC/LYP will save the division 65,625 man-hours per year. This project will recover all its costs and earn the division a nice "profit" just by being implemented. However, the major benefit will materialize when this tool is used to identify, document, and evaluate hundreds of repair process improvement efforts which increase serviceable life of end items and reduce the number of problem items.

4. LESSONS LEARNED

a. Depot repair of avionics is more effective if the current failure is evaluated in terms of prior performance, failure, and repair history. There is a discernible cause and effect to every failure. The balancing point in determining the benefit of learning the cause-and-effect relationship is the cost of data collection/storage/retrieval versus the net gain of a permanent fix.

b. Serial number tracking is required to determine which end items have chronic problems and which ones fail in an acceptable random pattern.

c. Data collection and retrieval ought to occur at the workstation whether it be a test station or repair bench. This gives the technician a sense of ownership in the process. This is probably an even greater benefit than the time and effort reduction.

d. Automated on-line data collection and retrieval are preferable to manual and batch methods because of the following:

(1) Accuracy is higher due to machine-readable images and programmatic editing and verifying of keyboard inputs.

(2) There is less chance data will be missed.

(3) Technicians will use data more frequently if it is instantly available and easily sorted into an understandable format.

(4) It can be shared through networks and electronic data communications techniques with other organizations.

(5) Data which is quickly and easily accessible will create its own demand. For example, a quality team evaluating a particular problem may research additional related data if it is readily available.

(6) Sorting, formatting, and analyzing the data can be performed at machine speed by technicians at their work site. These folks need to have results at the time that repair and testing of end items are taking place.

(7) Repair history stored anywhere except the technician's individual work site is used less than when it is immediately available. Likewise, data input tends to get batched and may become "cold" if the technician has to leave his work site to do the recording.

5. IMPLEMENTATION

Approach

WR-ALC/LYP has 38 production lines, with approximately 20 technicians per line. Each line will be equipped with:

One bar code reading wand per technician.

One bar code printer per line.

One interactive terminal per work group (two per line, minimum).

One dot matrix printer per line.

One supervisor's terminal.

One supervisor's dot matrix printer.

Other equipment consists of port concentrators, terminal controllers, and data communications wiring, as needed. A part of the data communications will provide on-line access for schedulers, planners, and management, as well as field-using organizations. Terminals and dot matrix printers are being acquired through reutilization with enough already on hand to meet minimum needs. WR-ALC/LYP will purchase the bar code readers, bar code printers, port concentrators, and connectivity items over the 2-year implementation period. The long-range goal is to give every technician some type of interactive device.

Status

Through an initiative unrelated to this project, WR-ALC/LYP has installed microcomputers on all production lines and in all production support functions. An effort is currently under way to install a suitable network

throughout the division and provide bridges to existing networks both within and outside WR-ALC/LYP. A decision has been made to redesign the implementation of this project to be hosted on the microcomputers.

There are short-term negative effects associated with this decision. They are:

- a. Programs written to run on the minicomputers have to be rewritten to run on microcomputers.
- b. Centralized minicomputer databases will be redesigned into many localized databases. Summary databases will be placed on network servers for access by organizations outside the production line environment.
- c. More people will be involved in the implementation. Some will have interests which may take precedence over this project.
- d. There will be some delay due to the acquisition and installation of additional equipment.

The long-term positive effect is that the project can expect a longer term of supportability and will be easier to upgrade when hosted on a microcomputer network. We believe that this is an appropriate decision and will make the project more viable in later years. Also, this reflects the original plan for the project.

Currently, software changes are being made to the programs which reside in the bar code readers and terminal controllers. As of 1 March 1993, we have a purchase contract pending for two complete microcomputer software development workstations. These should be operational by the end of April. They will host the rewriting of applications which were originally written on the minicomputers. We are also in the Computer Systems Requirements Document (CSRD) approval phase of establishing the computer network.

It is expected that the four production lines which were the original prototype area will be rewired and serve as the prototype area for the new microcomputer-based approach as well.

Validation of Savings

Savings realized through use of electronic data communications techniques are determined simply by counting the number of end items processed in the shop. An average of 35 minutes will be saved on every end item.

Savings realized through using this project as a tool to identify, document, and evaluate improvements which increase serviceable life and reduce the number of problem end items will be self-documenting. Reports will be generated which link improvement efforts to changes in serviceable life (the number of flying hours between failures). This is the heart of the project. There can be an unlimited number of improvement efforts being documented and evaluated concurrently. Whether the payback is great or small, it will not be canceled by any extra time and effort spent documenting and evaluating it.

Periodic reports will be made to WR-ALC/LYP on the status, operation, and accomplishments of the project.

Implementation Schedule: See Appendix B on page 13.

6. ECONOMIC SUMMARY

PRAM Project Cost: \$ 122,505

a. Purchase commercial bar code equipment	\$ 32,505
b. Work order for software programming	90,000
Total PRAM investment	\$ 122,505

Implementation Cost: \$ 400,000

a. Purchase commercial bar code equipment	\$ 376,400 (Based on GSA and commercial price lists to fully equip 32 remaining production lines.)
b. Network server microcomputers	23,600
Total implementation purchase	\$ 400,000

Equipment maintenance and system administration will be covered by support organizations already existing within WR-ALC/LYP.

The project expects to generate savings through:

a. Increased serviceable life and reduced number of problem end items. However, this project is just the tool by which improvement efforts to achieve these goals are documented and evaluated. Increased serviceable life benefits and the reduction of problem end items will be attributed to the improvement efforts which produce them, not to this project.

b. Decreased shop flow time resulting from the paperless implementation concept and utilization of electronic data communication techniques. WR-ALC/LYP produces 125,000 end items per year. SMART Shop will save 35 minutes per end item, multiplying this times 125,000 items equals 72,917 hours per year. The 72,917 hours is reduced by 10 percent to allow for manual bar code scanning. The result is a projected 65,625 hours reduction in shop flow time per year. Using \$30 per hour, which is a very low estimate of the cost of personnel plus overhead, the resulting savings is \$1,968,750 per year. Over a 10-year period this translates to a savings of \$19,687,500 and a return on investment (ROI) OF 36.7.

$$\text{ROI} = \frac{\text{GS} - (\text{PC} + \text{IC})}{(\text{PC} + \text{IC})} = \frac{\$19,687,500 - (122,505 + 400,000)}{(122,505 + 400,000)} = 36.7$$

COORDINATION

Statistical Maintenance and Repair Techniques (SMART) Shop

ORGANIZATION	SIGNATURE	DATE
LYPDD	<u>Jeffrey L. B.</u>	<u>24 March 93</u>
LYPD	<u>Paul Buhler</u>	<u>24 Mar 93</u>
LYP	<u>R.W. Smith</u>	<u>3-25-93</u>
LY	<u>James Stoner</u>	<u>16 Mar 93</u>
DS	<u>Robert Stanfield Jr.</u>	<u>5 May '93</u>
TI	<u>St. J.</u>	<u>10 May 93</u>

COORDINATION

Statistical Maintenance and Repair Techniques (SMART) Shop

ORGANIZATION

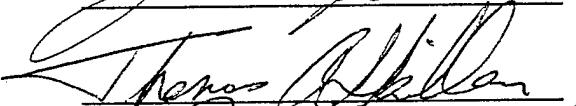
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DATE

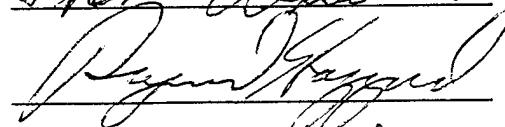
SES

31 Mar 93

CNT (PRAM Mgr)

24 Mar 93

CNT

2 Apr 93

CN

26 MAR 93

Appendix A

SURVEY SUMMARY OF ACTIONS TO BE REPLACED BY DATA COMMUNICATIONS

AND

SUBSTITUTED BY BAR CODE SCANNING

	R/S	Avg Time	Notes
		Mins	
End item-specific, outside shop tasks			
Signature receipting into WR-ALC/LYP	R	1.90	
Printing, stuffing blank AFMC FORM 959	R	2.29	
Clearing Intransit	R	1.22	
Submit serviceable to WR-ALC/DS	S	1.00	
Key-to-disk AFTO FORM 349	R	0.50	estimated
End item-specific, inside shop tasks			
Transcribe DD FORM 1577-2 and AFTO FORM 350 to AFTO FORM 349	R	2.30	
Fill out DD FORM 1574 and DD FORM 1574-1	R	0.75	
Fill out AFMC FORM 424	R	1.89	
Fill out AFMC FORM 959	R	2.10	
Replacement components			
Signature receipting into WR-ALC/LYP	S	----	Spring 91
Fill out AFMC FORM 244	R	3.26	
Charge out to Control Number	S	1.94	
MIC replenishment	S	2.18	
Clearing Intransit	R	0.85	
General shop tasks			
Correlating component ref # to part #	R	1.98	
Correlating component part # to NSN	R	4.76	
Individual logbooks	R	2.65	
Review, authenticate test eqt calib	S	2.22	
Review, authenticate test eqt maint	R	1.70	
Total averages		35.49 minutes	

NOTES:

R = task to be replaced by data communications.

S = substituted by bar code scanning.

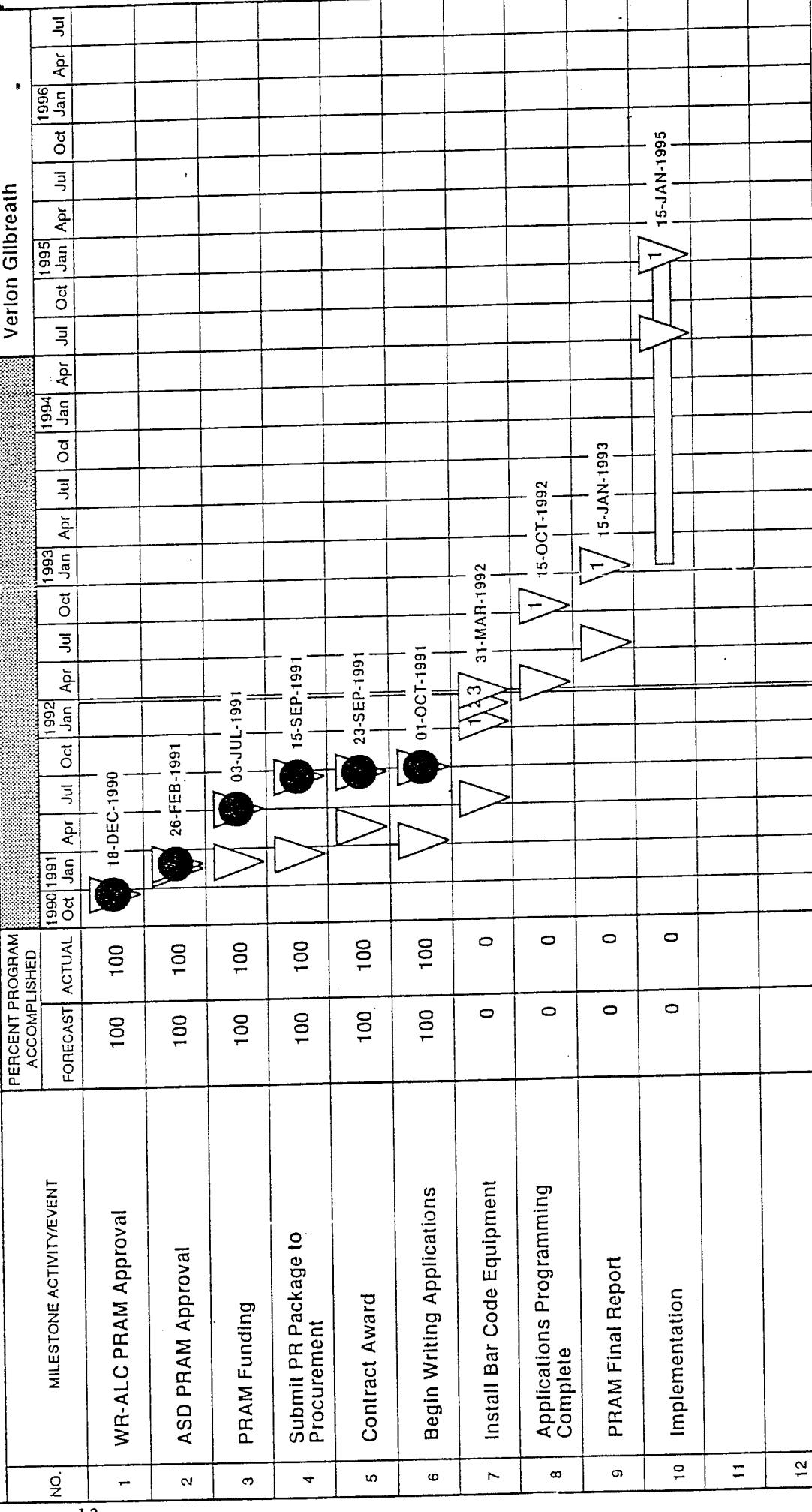
Survey data was obtained through a combination of self-survey forms completed by technicians as the tasks were being performed and by a surveyor watching the tasks being performed. Although results of the self-survey were generally higher (and represented a greater population sample) than that of the surveyor, the results of the two were averaged to give a more conservative representation.

SUBJECT UNDER REVIEW
Statistical Maintenance And Repair Techniques (SMART) Shop, TAB 5107

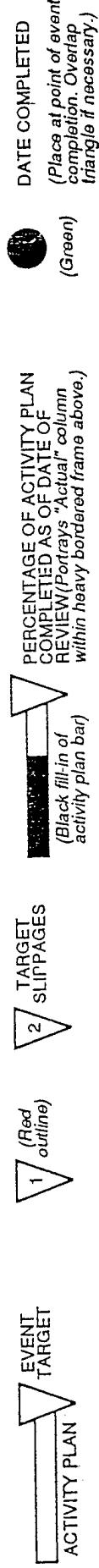
9100006 3 DATE REVIEWED
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REPORTING AGENCY & PROJECT MONITOR
LYPDD

Verlon Gilbreath



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HEADQUARTERS WARNER ROBINS AIR LOGISTICS CENTER (AFMC)

05 FEB 1993

FROM: WR-ALC/LYP

380 2nd St, Ste 104

Robins AFB, GA 31098-1638

SUBJ: Implementation Reaffirmation of PRAM Project WR-90352-02

TO: ASC/SMT (Attn: Joe Koos)

Bldg 22

2690 C St, Ste 5

Wright Patterson AFB, OH 45433-7412

1. PRAM project WR-90352-02 (known as the SMART Shop project) will be implemented throughout WR-ALC/LYP within the next two years. This division will benefit from this project in several areas. It will provide technical data collection and analysis by which we will evaluate and document improvements in the depot repair process. It will help us find areas of testing and repair which have potential improvement needs. SMART Shop satisfies the data collection requirements of the Two Level Maintenance concept. And the electronic data communications aspects of the project will greatly reduce the time now required by pencil and paper interaction with standard data systems external to the depot shop.

2. Under the original PRAM Project Plan SMART Shop would be hosted on a group of minicomputers acquired through reutilization. However, WR-ALC/LYP has now installed a sufficient number of microcomputers to allow rehosting the project in a distributed network configuration. We believe this will give us greater flexibility in implementation, less potential for downtime and extend the life expectancy of the project.

3. Funding for equipment, maintenance and personnel will be provided for through WR-ALC/LYP's budgetary process.

4. POC for the SMART Shop project is Verlon L. Gilbreath at DSN 468-2116.

A handwritten signature in black ink, appearing to read "R.W. WIMSETT".

R. W. WIMSETT, Deputy Chief
Production Division
Directorate of Avionics Management

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